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Note and record

Impending local extinction of *Aloe ferox* Mill. populations in the absence of elephants and black rhinos?

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Introduction

Elephants (*Loxodonta africana,* Blumenbach), and black rhinos (*Diceros bicornis*, L.) to a lesser extent, have been associated with local extinctions of tree *Aloe* and *Euphorbia* populations (Penzhorn, Robbertse & Olivier, 1974; Lombard *et al.*, 2001; Parker & Bernard, 2008, 2009; Cowling *et al.*, 2009). Here, we focus on *Aloe ferox* Mill., which is a characteristic feature of the Eastern Cape flora, often found in dense stands throughout the region. The increase of *A. ferox* populations, as well as other tree aloes and euphorbias, has been attributed to the historical decline of megaherbivores, especially elephants (Cowling & Pierce, 2009; Cowling *et al.*, 2009). In this study, we set out to quantify earlier field observations of declining *A. ferox* populations in the absence of elephants and black rhinos.

The physiognomy of aloes makes them highly susceptible to herbivory (Breebaart, Bhikraj & O'Connor, 2002b; O'Connor, Goodman & Clegg, 2007; Shackleton & Gambiza, 2007; Parker & Bernard, 2008, 2009). For example, indigenous herbivores such as bushbuck, warthogs, vervet monkeys, black rhino, eland, greater kudu, porcupines and chacma baboons have been described to have negative effects on aloe populations (Breebaart, Bhikraj & O'Connor, 2002a; Shackleton & Gambiza, 2007; Parker & Bernard, 2008, 2009). Elephants in particular may cause a great deal of damage, and if present at high densities, they can be a major contributor to large declines in aloe populations (Penzhorn, Robbertse & Olivier, 1974; Barratt & Hall-Martin, 1991). Domestic herbivores such as boer goats can have negative influences on aloe populations (Breebaart, Bhikraj and O'Connor, 2002a,b), but this has not been found in other studies (e.g. Hester, Scogings & Trollope, 2006).

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Methods

Here, we report demographic patterns for *A. ferox* populations exposed to different herbivore pressures, specifically domestic and/or indigenous herbivores in enclosed farmlands (i.e. livestock farms or private game reserves), but importantly in the absence of any megaherbivores, such as elephants and black rhinos. Private game reserves with indigenous herbivores were previously livestock farms. We sampled between 40 and 60 individuals at six sites. Stem height (i.e. length) of *A. ferox* individuals was measured, but only up to the base of living rosettes. Shackleton & Gambiza (2007) describe the difficulties encountered when trying to determine the height of the living rosette as turgor pressure changes the orientation of the leaves. By applying a wide bin range (e.g. 0.5 m), we considered stem height a reasonable proxy for plant age and demography.

Results

We found no evidence of a demographic bottleneck at sites dominated by domestic herbivores (sites A and B; Fig. 1). In contrast, we found a clear demographic bottleneck at sites exposed to large indigenous herbivores – mainly greater kudu (*Tragelaphus strepsiceros)* for more than 20 years (sites D, E and F; Fig. 1). In a population recently converted from a livestock farm to an private game reserve (site C), it appears that a demographic bottleneck is developing between 0.25 and 1 m. Site D is the only site that experiences fire, and this may also contribute to the loss of individuals in the small size classes. Site B has a low occurrence of individuals between 0.25 and 0.5 m, and we suspect that this is due to trampling by cattle and requires further investigation. The demographic bottleneck at sites C, E and F exposed to indigenous herbivores will have

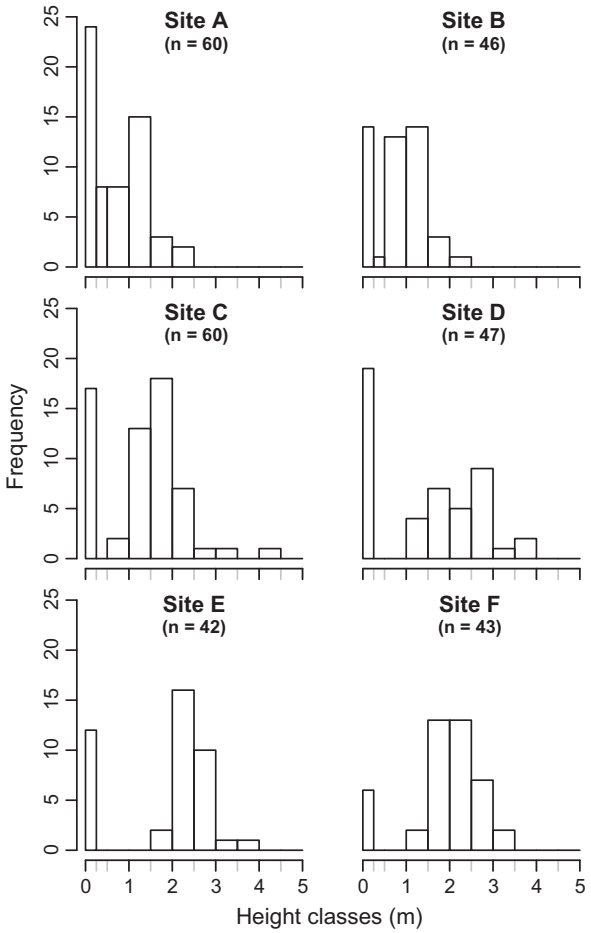

Fig 1 The frequency of *Aloe ferox* height classes at six sites with different domestic and indigenous herbivory exposure. The first two height classes are 25 cm bins, and thereafter 50 cm. Site A and B have been under domestic herbivory for more than five decades. Site C has recently transitioned (since 2012) from domestic to game farming. Site D, E and F have transitioned from domestic to game farming in 1982. Sites were found in the following vegetation types: Nama-Karoo: A, B, C and E; Grassland: D; Nama-Karoo–Grassland transition: F. Farm history was obtained from personal communication with Ian Ritchie, farm manager at Kaboega Farm. Site coordinates are: A: S33.181959°, E25.742632°; B: S33.266894°, 25.546442°; C: S33.210214°, E25.514539°; E: S33.256939°, E25.475311°; F: S33.255438°, E25.392159°; F: S33.255143°, E25.422404°.

knock on effects for recruitment in subsequent size classes. Based on the growth rates measured by Shackleton & Gambiza (2007), 50 cm of growth represents approximately 17 years (10–30 years using the extreme growth rates reported). Thus, a missing size class in site E (0.25–2 m) could represent approximately 62 years of growth. Such a large time span suggests that this is not a recruitment bottleneck due to unfavourable climatic events (e.g. drought).

Discussion

Demographic bottlenecks may ultimately lead to population extinction. We detected bottlenecks in areas where indigenous herbivores, excluding elephants and black rhinos, are returning to the landscape. Our results suggest that the height classes above two metres are relatively resistant to herbivory, including large indigenous browsers such as kudu. However, if the bottleneck continues in the lower height classes, we can expect local population extinction within 70–100 years, given that the probability of toppling increases with height (i.e. this species has a maximal height before the root structure can no longer support the stem).

This study is an additional piece of the puzzle regarding the anthropogenic impacts on the natural landscapes of the Eastern Cape. In the late 1700s, the introduction of settled livestock farming in this region resulted in widespread, but gradual degradation, of ecosystems (Lechmere-Oertel, Kerley & Cowling, 2005; Cowling & Pierce, 2009). The parallel extirpation of indigenous herbivores, including elephants, black rhinos and large browsers such as kudu, is – together with habitat destruction – regarded as the reason for massive increases in the populations and distributions of tree aloes. Here, we find that the return of indigenous herbivores is reversing this trend as demographic bottlenecks have formed. We suspect that the greatest role player for this reversal is kudu, and we note that kudu populations have been expanding in the region without human intervention (Skead, 2007).

In conclusion, we found evidence of a demographic bottleneck in populations that have been re-exposed to indigenous herbivores, but not to elephants or black rhinos. This suggests that the expansion of aloes was caused by the loss of the suite of indigenous herbivores and not only due to the decline of these megaherbivores. Game farming is becoming a popular alternative to domestic livestock farming (Smith & Wilson, 2002; Carruthers, 2008). This will result in a mosaic-like loss of *A. ferox* in the Eastern Cape landscape in areas not protected by steep topography, which offers refugia from herbivory (Cowling *et al.*, 2009), and we argue that local extinctions should not be seen as an indicator of a larger loss of biodiversity.

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